

Infrared Studies of the Reflective Properties of Solar Cells of the HS376 Spacecraft

James Frith¹
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Jacqueline Reyes¹, Phillip Anz-Meador², Heather Cowardin¹, Brent Buckalew², Susan Lederer³

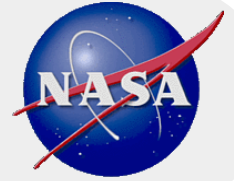
¹*Univ. Texas El Paso*

²*JETS/Jacobs*

³*NASA Johnson Space Center*

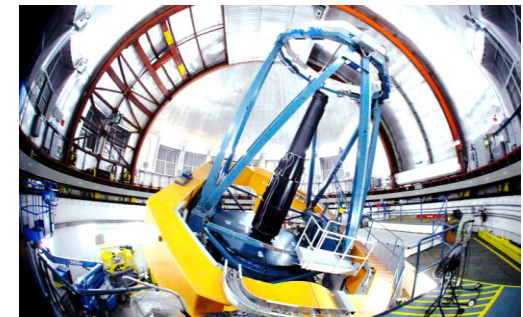


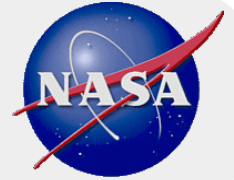
JACOBSTM



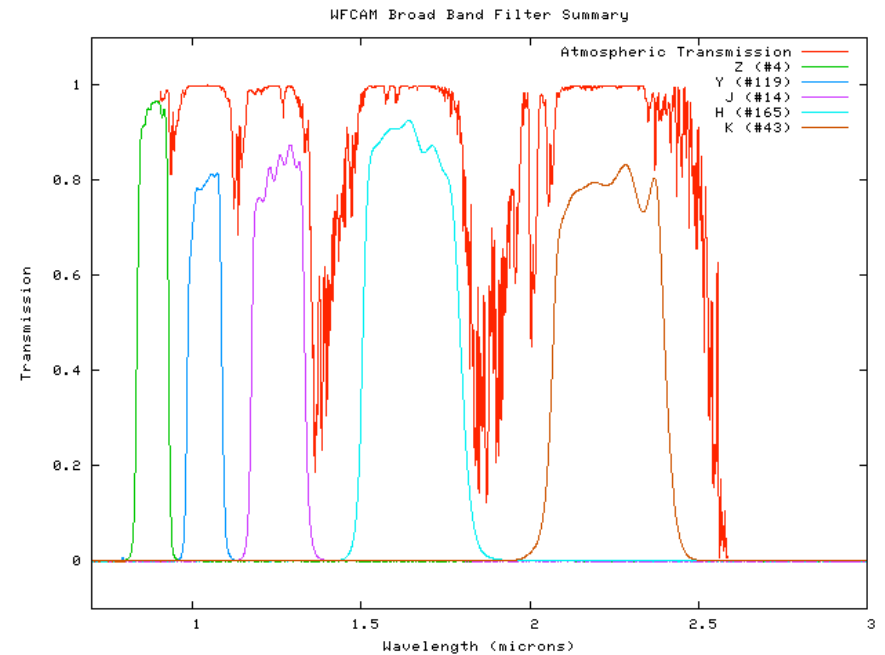
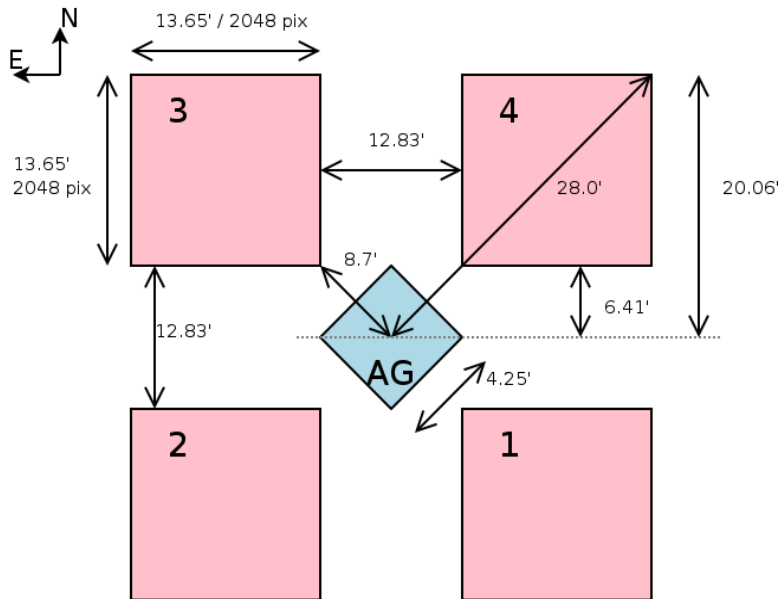
United Kingdom Infrared Telescope

- Long history of providing high quality infrared observations to the astronomical community
- Capable of both photometry and spectroscopy
 - NIR Camera
 - 1-5 micron low resolution spectroscopy
 - 5-25 micron high resolution spectroscopy
- Extremely efficient software pipeline via the Cambridge Astronomical Survey Unit
- Both telescope and software pipeline have been recently modified for man-made object tracking and analysis.





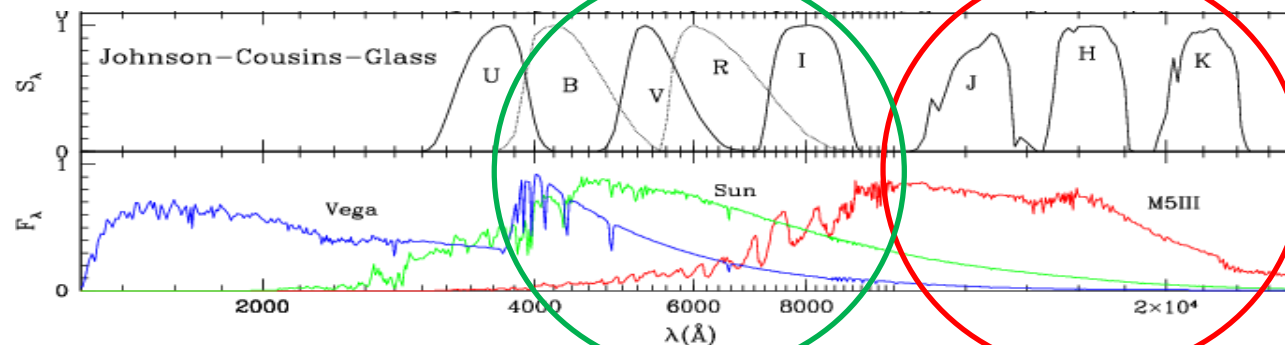
Wide Field Camera (WFCAM)

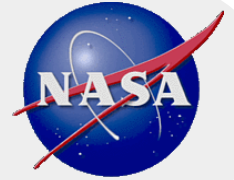


4 separated Rockwell Hawaii-II (HgCdTe 2048x2048)

MCAT

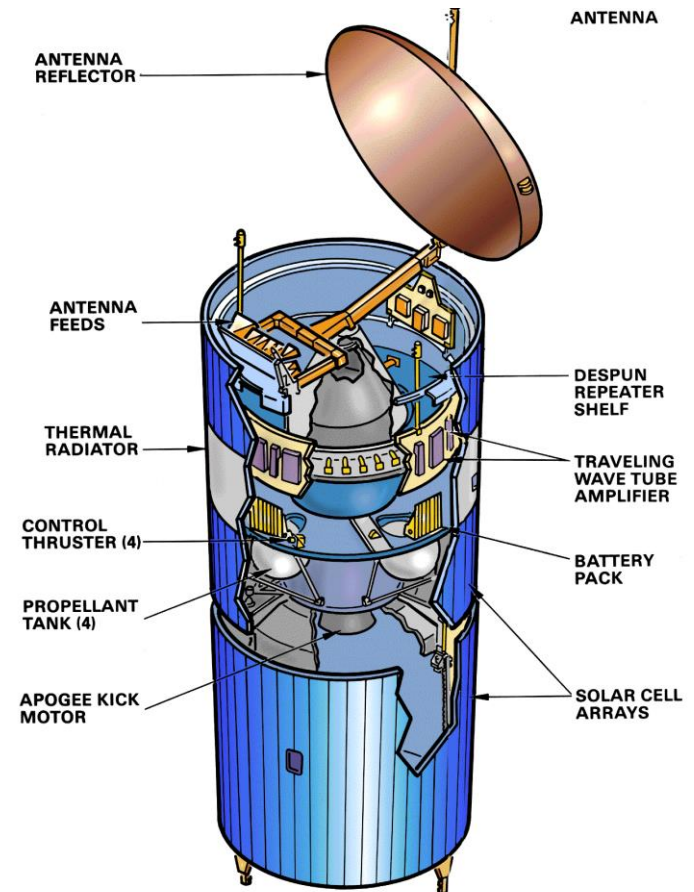
UKIRT - WFCAM



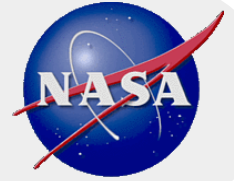


Hughes/Being HS-376 Spacecraft

- Simple geometry
- More than 50 launched from 1980 to 2003 into Geo orbits.
- Roughly 2 meter diameter spin-stabilized cylinder covered primarily in solar cells
- Near-identical physical characteristics and similar materials help constrain albedo/size ambiguity

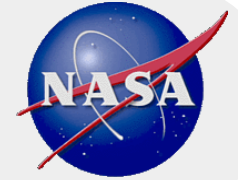


**BOEING 376
SPACECRAFT CONFIGURATION**

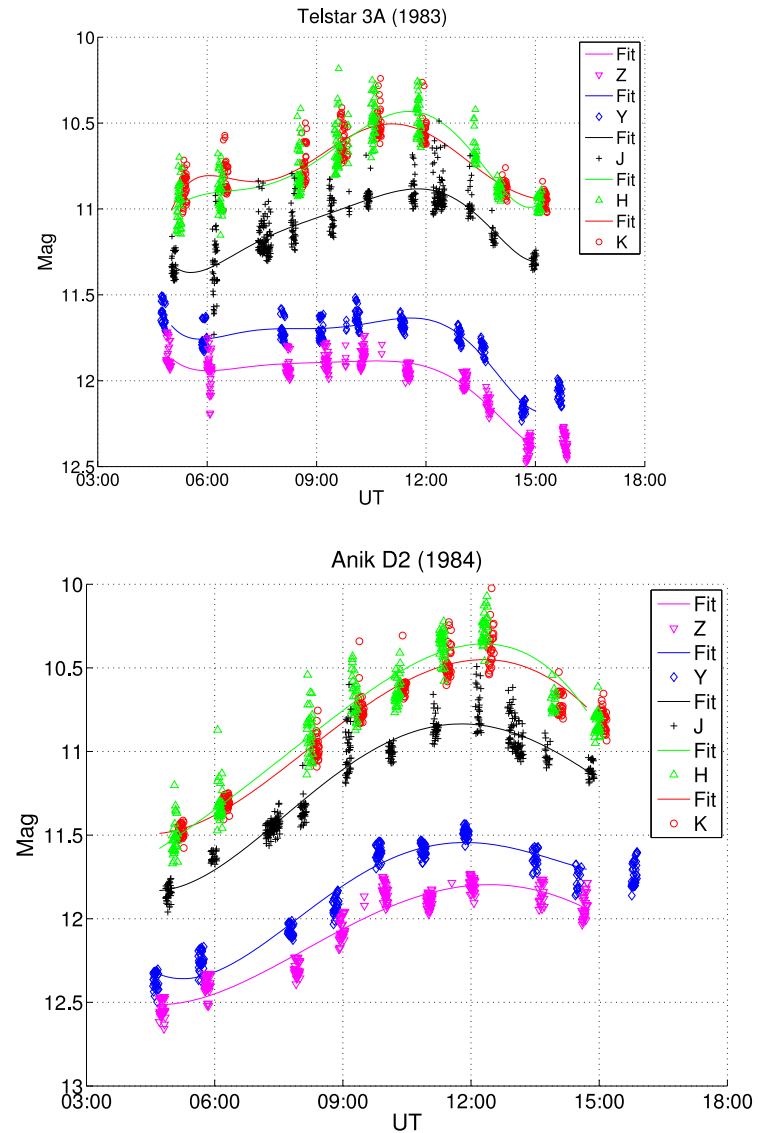
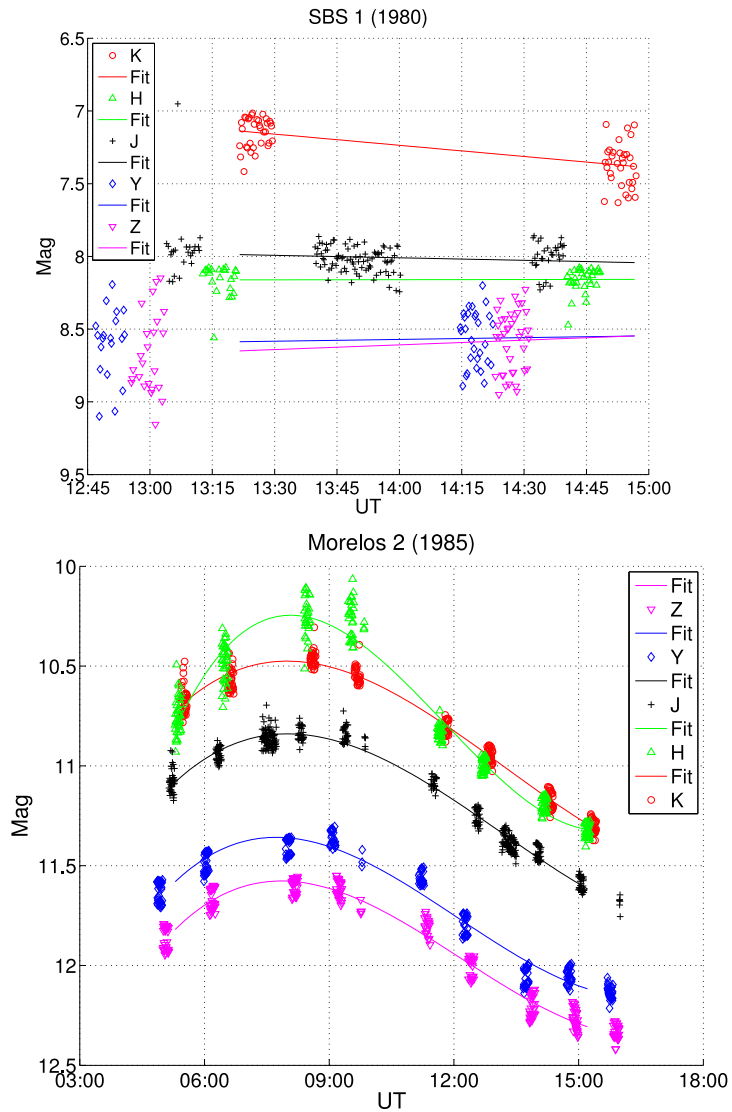


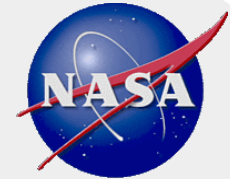
Solar Cells Used

- **K4 3/4:** Shallow junction n/p Si cell with back surface reflector
- **K7:** Shallow junction n/p Si cell with back surface field, back surface reflector and textured front surface
- **GaAs/Ge:** p/n single junction GaAs device grown on Ge substrate
- **GaInP2/GaAs/Ge:** Dual junction n/p device grown on inactive Ge substrate

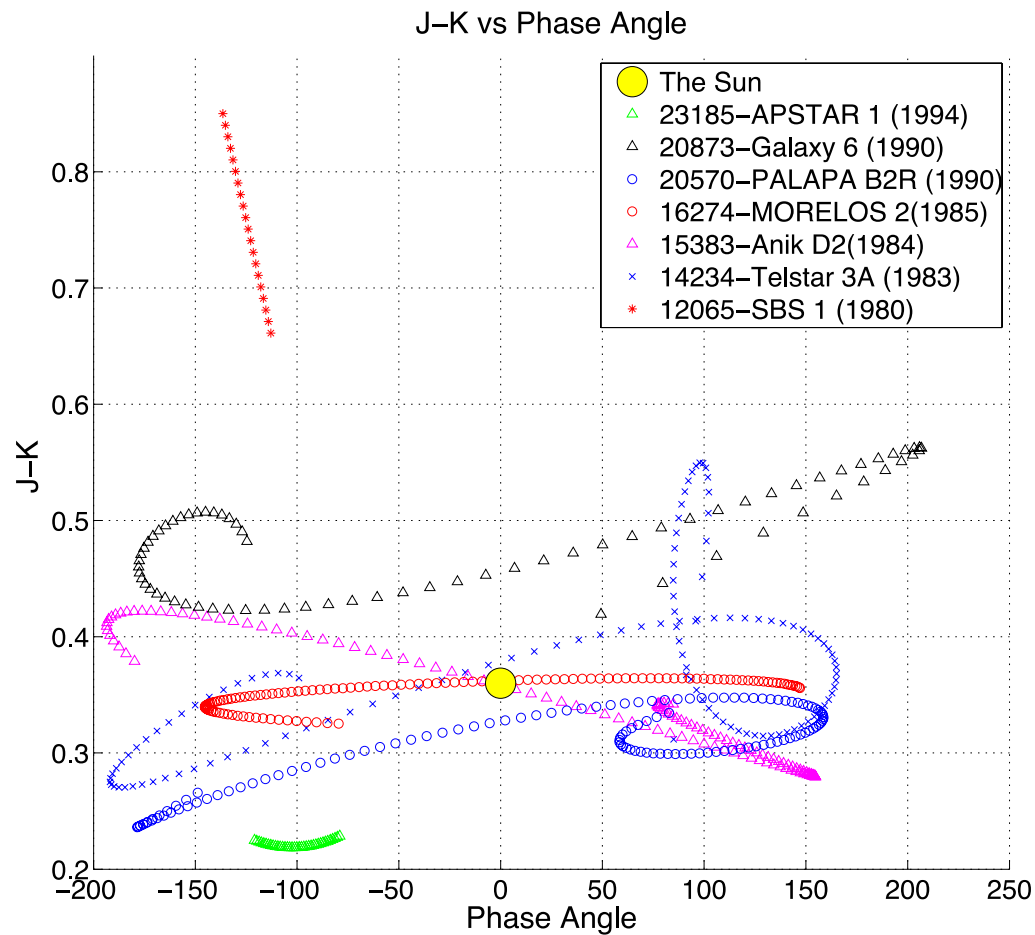


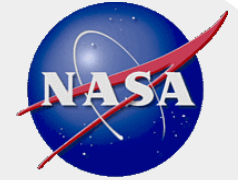
Light Curves



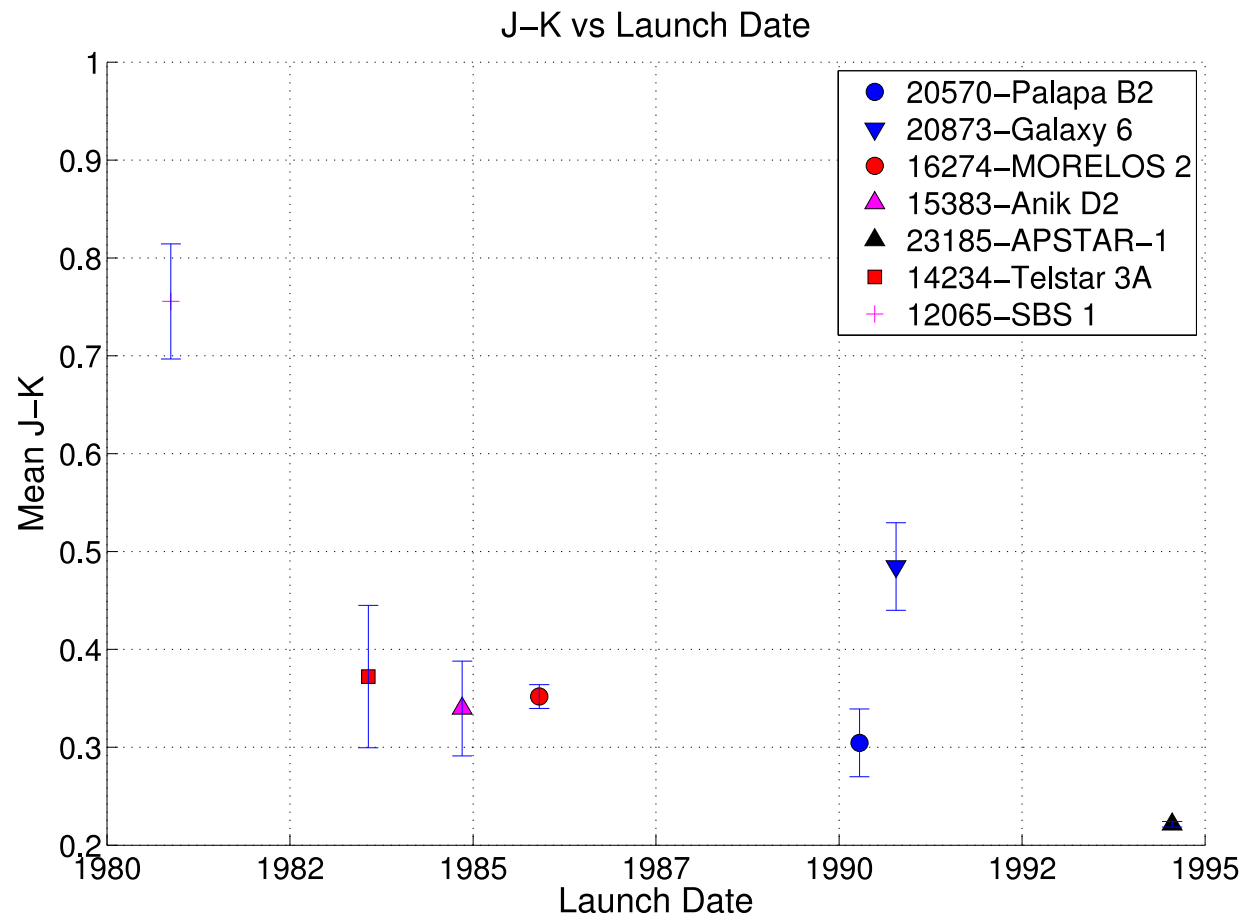


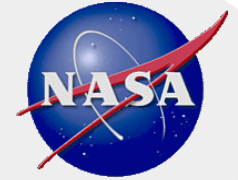
Color vs Phase



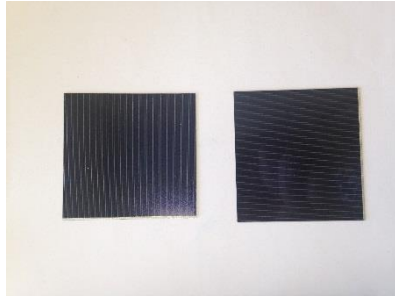


Mean Color vs Launch Date

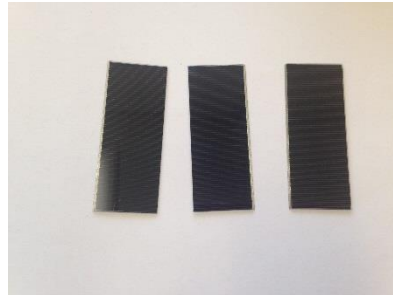




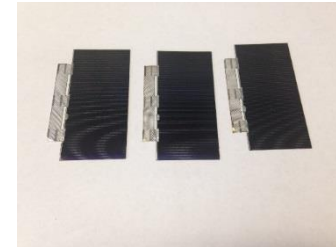
Spectra collected in the Optical Measurement Center at NASA JSC



Silicon K4
3/4



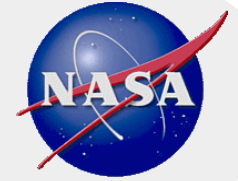
Silicon K7



GaAs/Ge
Solar Cells

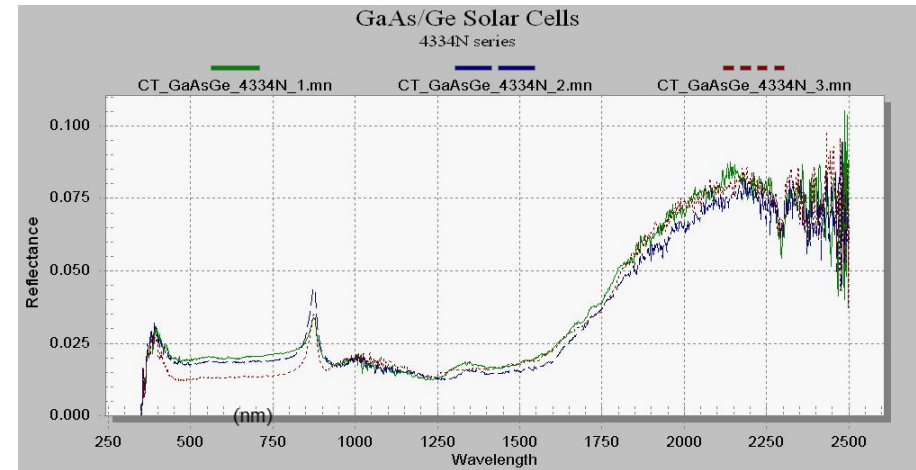
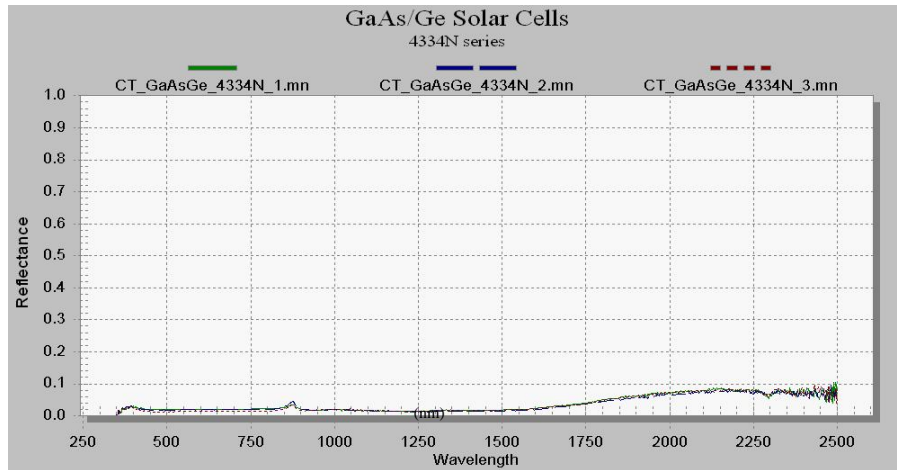


Dual
Junction:
GaInP₂/GaAs
on Ge

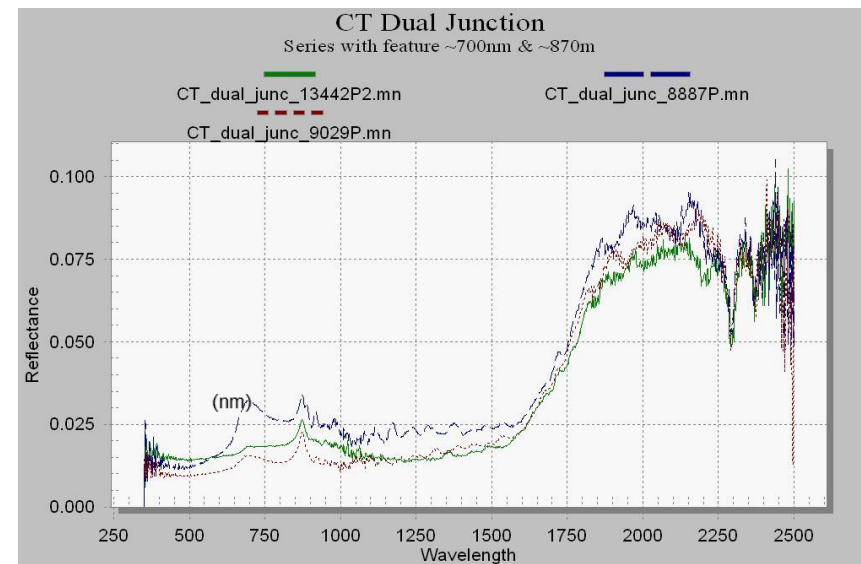


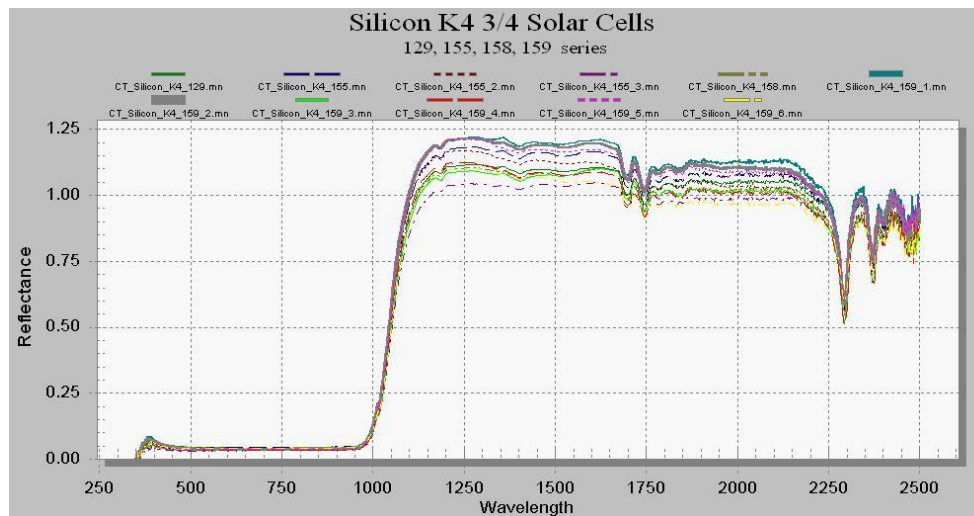
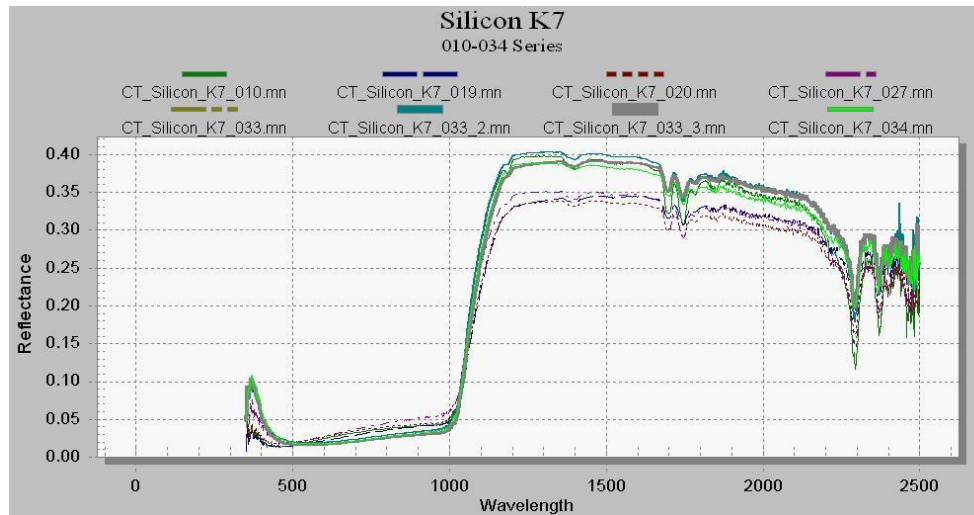
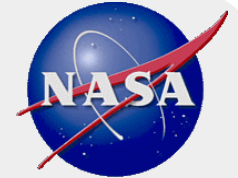
OMC Spectroscopy: Solar Cells

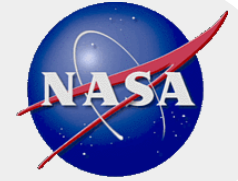
- ~200 spectral measurement readings of various solar cells



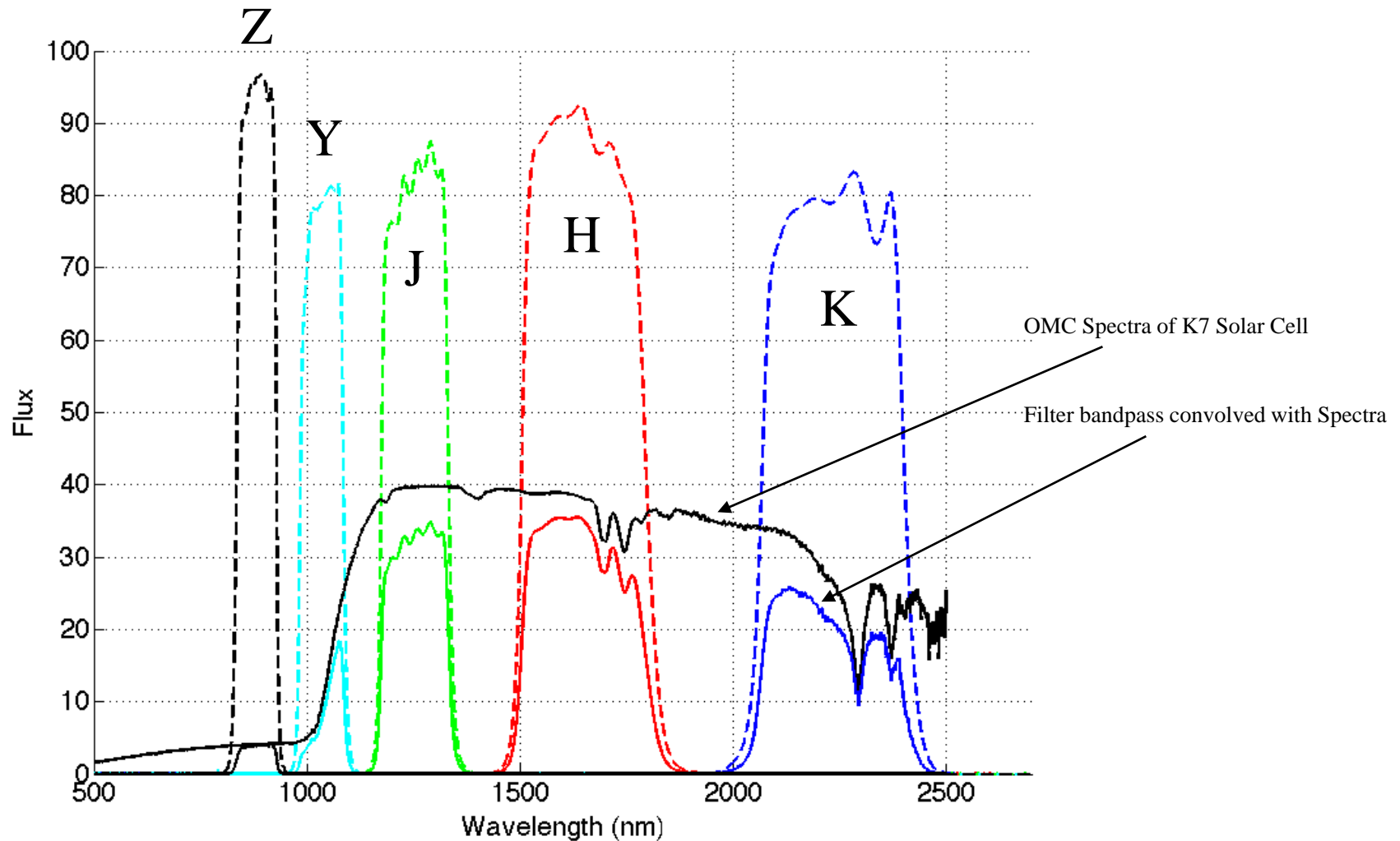
- Ge QE correlates with peak at ~850nm
- CT Dual Junction: GaInP₂/GaAs on Ge
- GaInP₂ QE correlates with peak at ~700nm

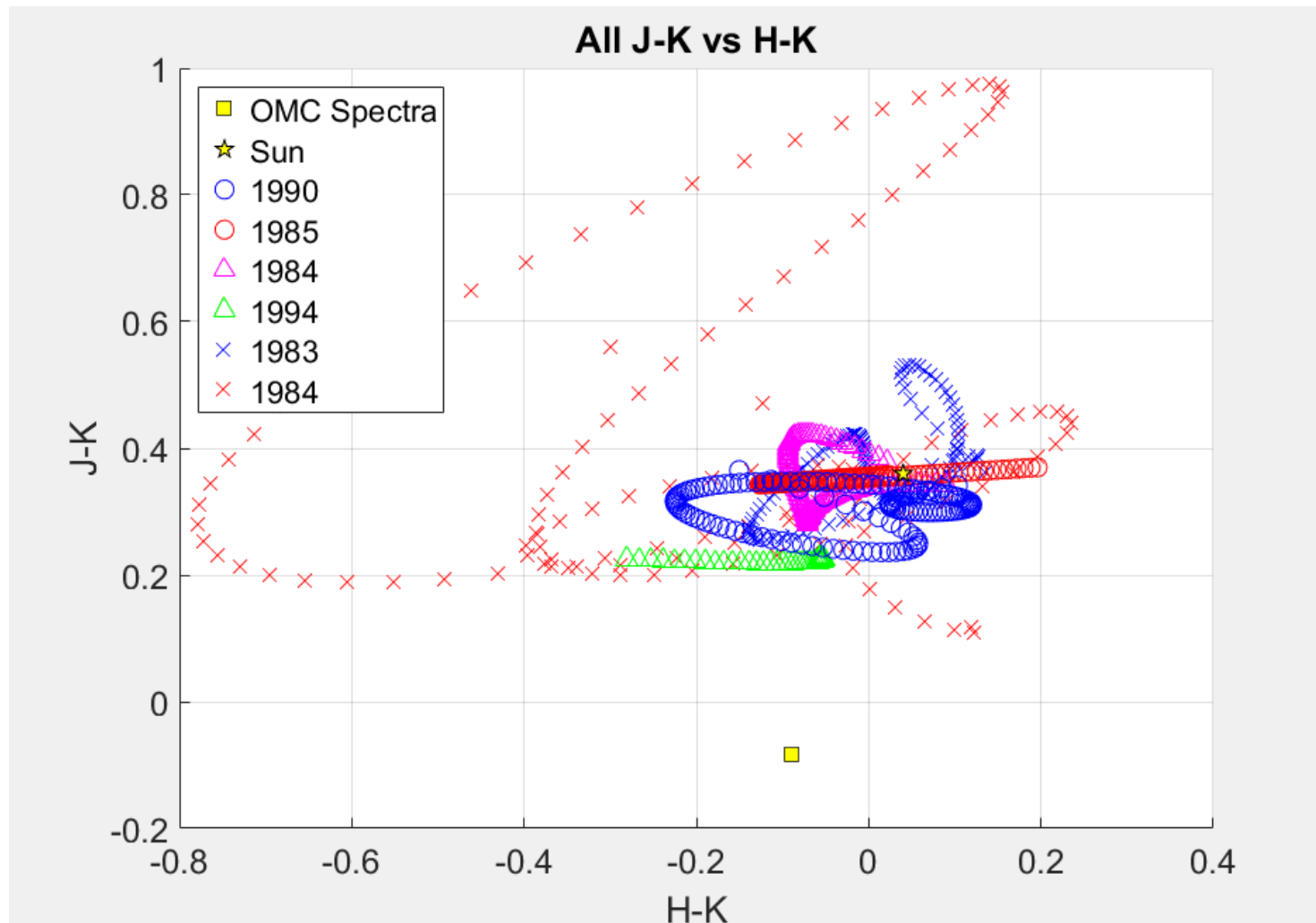
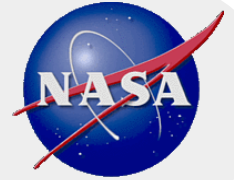


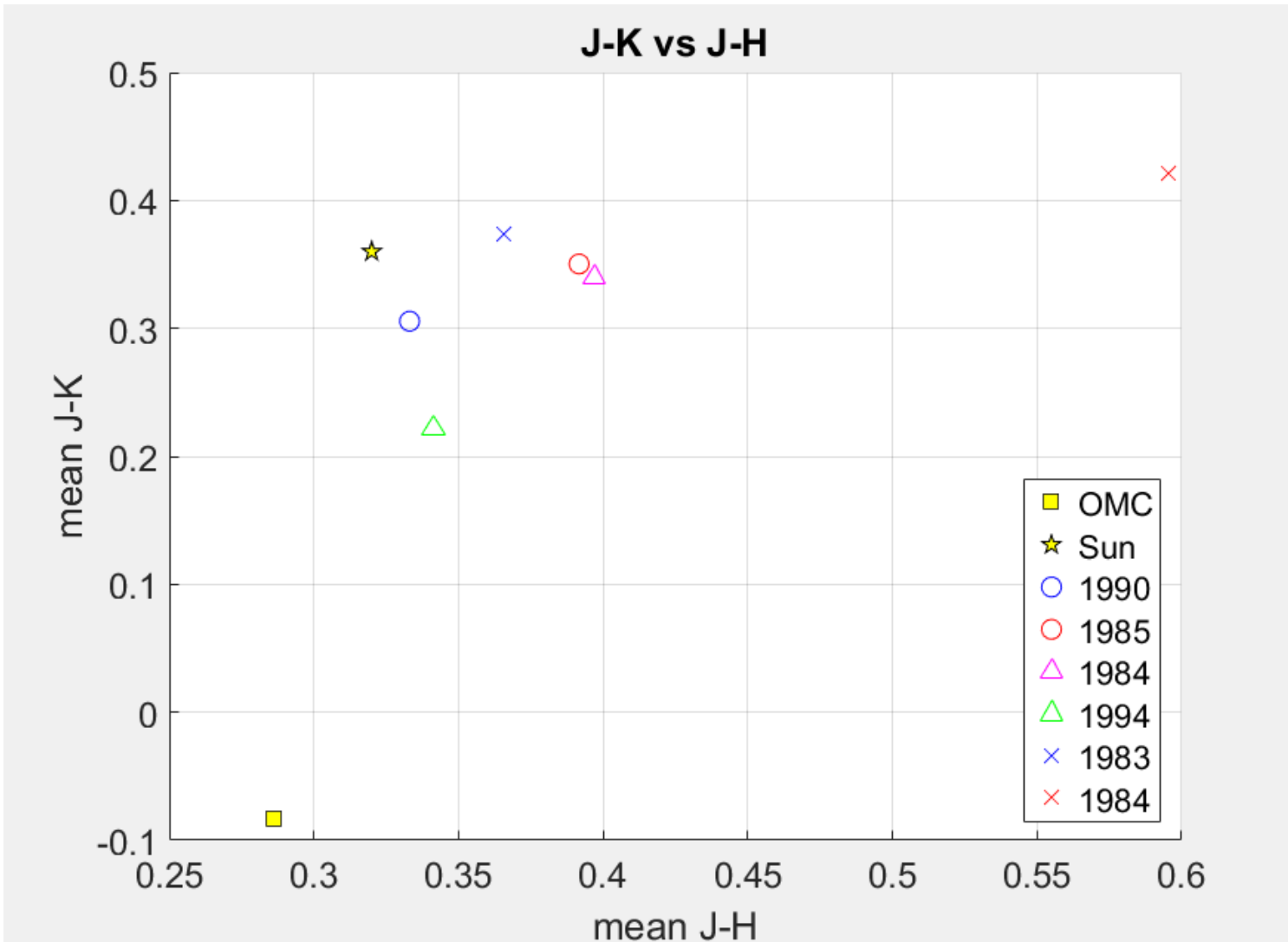
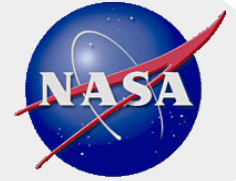


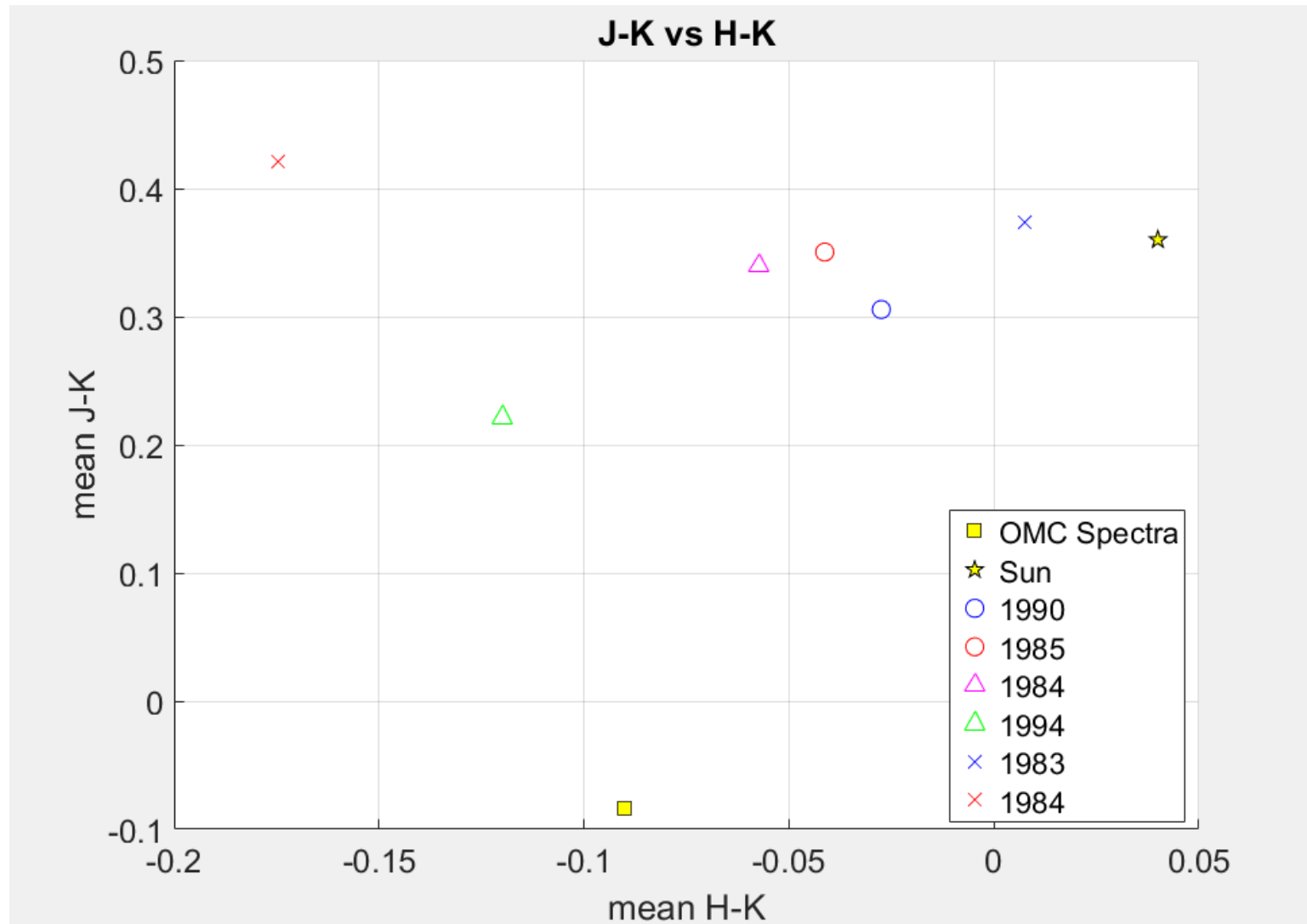
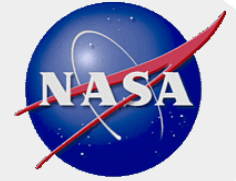


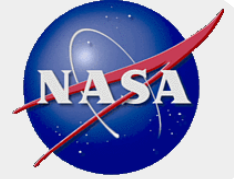
OMC Spectroscopy compared to UKIRT photometry





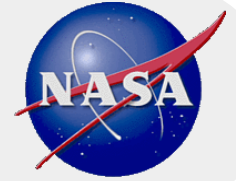




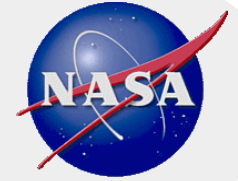


Future Work

- Continue studies with UKIRT spectra
- Observe HS376s with non-silicon based solar cells and compare
- Spectral unmixing spectra for material analysis (in progress)
- Investigate known space weathering effects
- Better refine ground based spectra to on-orbit comparison



Backup



Spectroscopy

- **Spectrum** → **Measuring light energy at various wavelengths**
- **Spectrometer** → **Reflectance Curve (spectrum)**
- **Reflectance curve** → **material composition in FOV of instrument**
- **Examine maxima and minima of reflectance curves**
- **Minima** → **Molecular Absorption = Absorption Bands**
- **Maxima** → **Reflecting areas**

} Analyzing Slopes on Reflectance Curves

Material Characterization

- Aluminum = 850 nm
- Copper/Gold = 450 nm
- Solar Panels = close to 0 (flat)
- Organics
- White Paint

Reflectance Spectrometer

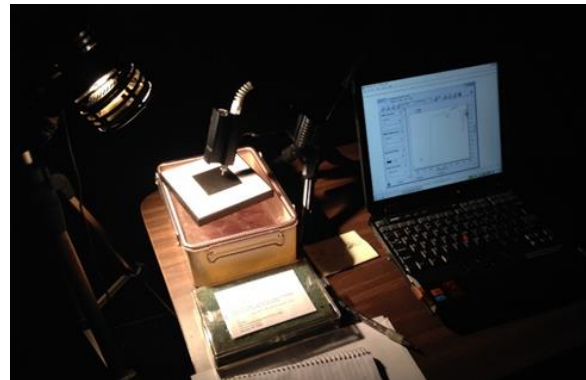
- **Broad Range from 300-2500 nm**
- **3 spectrometers in system**
 1. VNIR: 300nm – 1,000nm
 2. SWIR 1: 1,000nm – 1,850nm
 3. SWIR 2: 1,850nm – 2,500nm

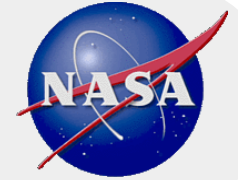
Procedure

- **Pistol and lamp @ 90°**
- **Pistol perpendicular to target surface**
- **Calibrate using Spectralon (white reference material)**
- **Computer program records data**

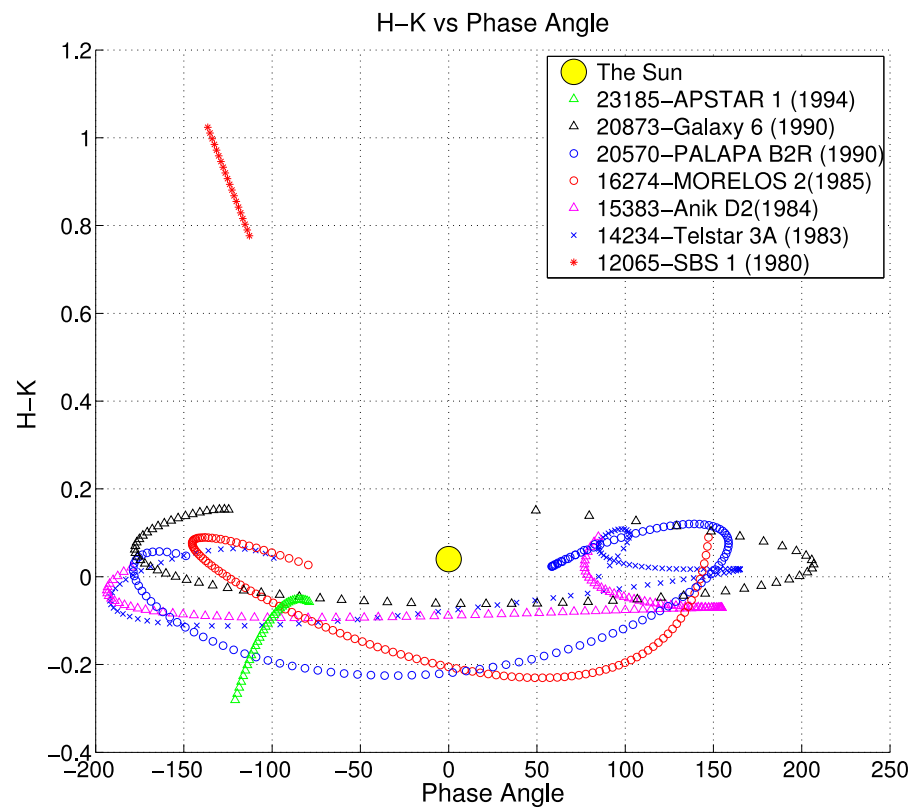
Requirements

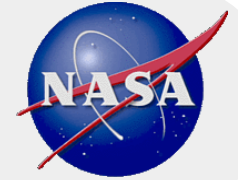
- **Dark Lab**
- **Powder Free Latex Gloves**
- **Patience & a steady hand**



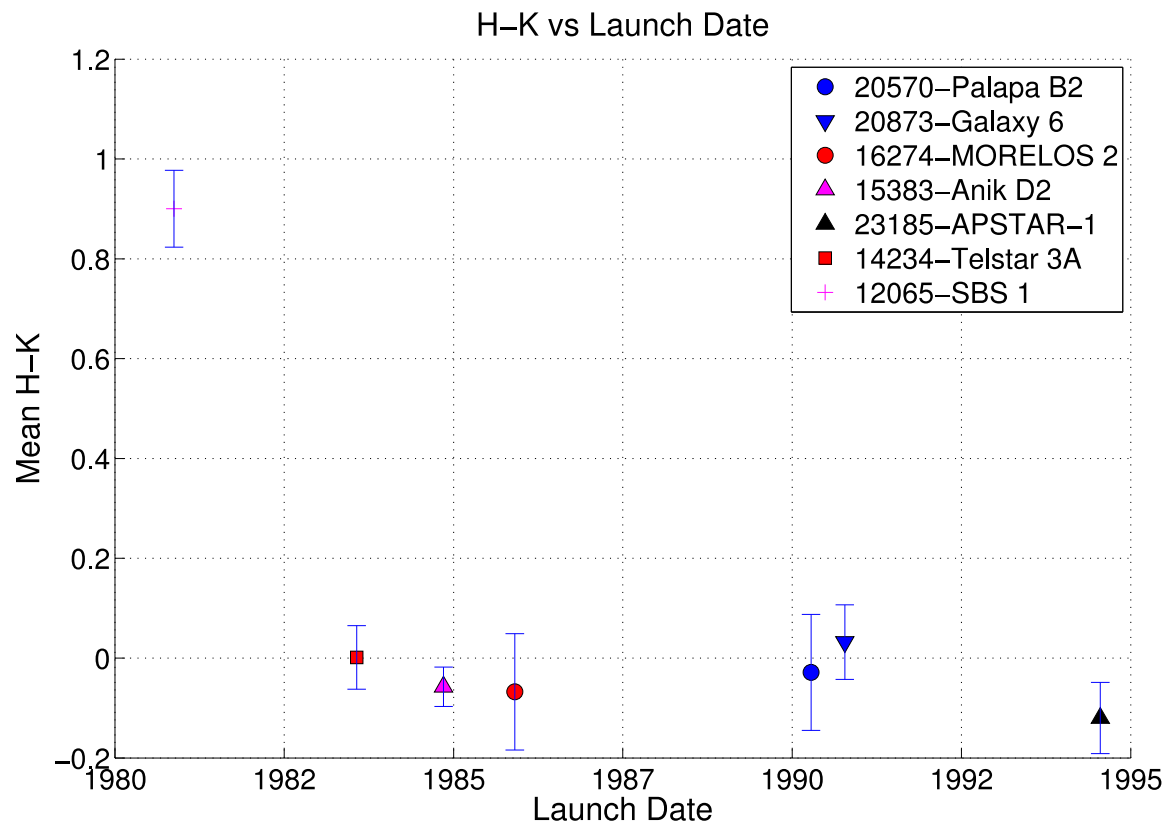


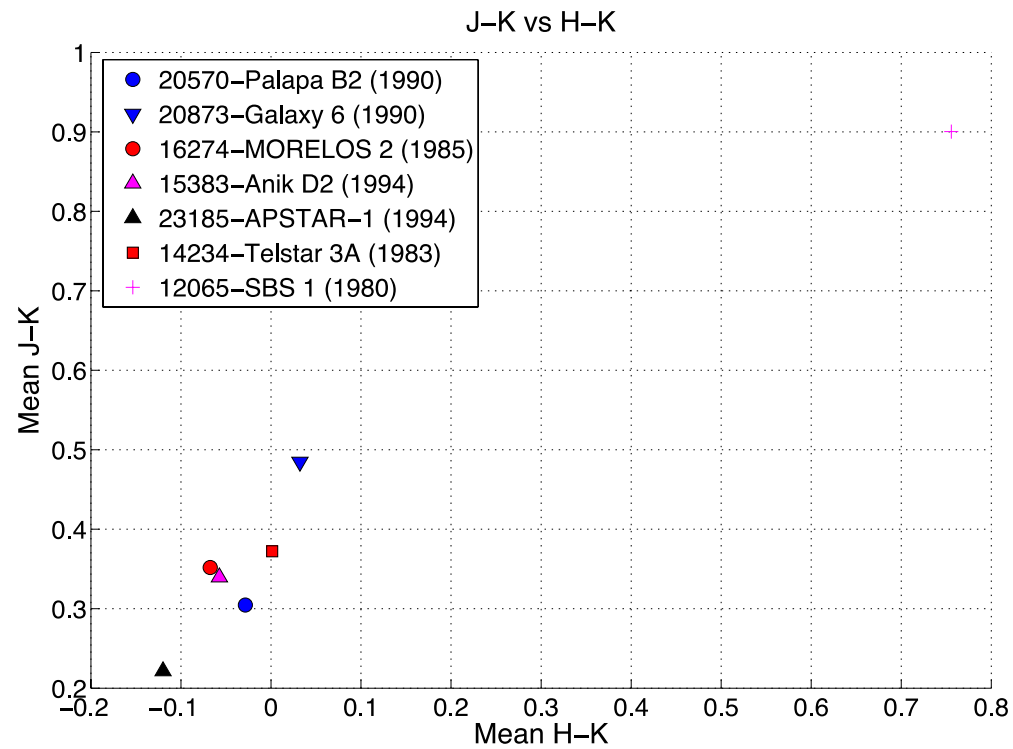
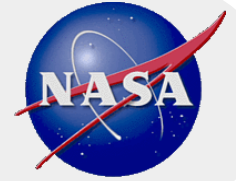
Color vs Phase

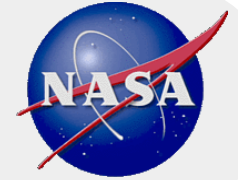




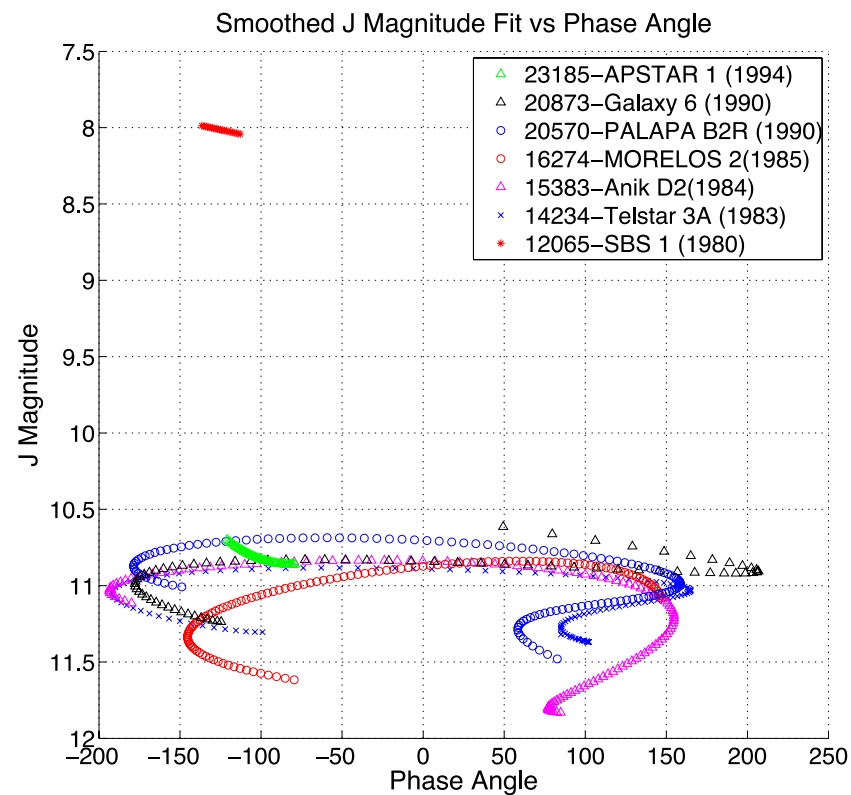
Mean Color vs Launch Date

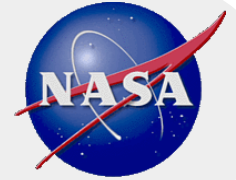




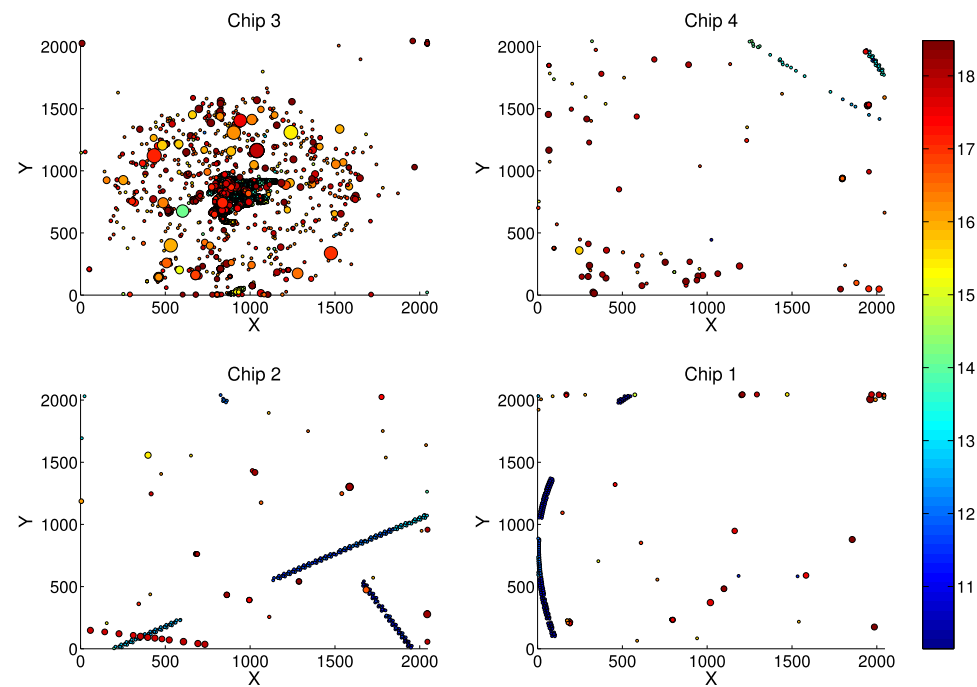


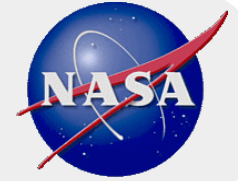
Magnitude Comparison





Detection Filtering

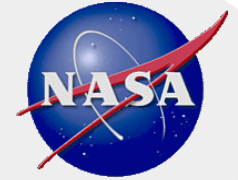




Nov 2014 Observations

Int Des	SSN #	Launch Year	Name	Length Deployed	Diameter	On-orbit Mass
1980-091A	12065	1980	SBS 1	6.6 m	2.16 m	540 kg
1983-077A	14234	1983	Telstar 3A	6.84 m	2.16 m	653 kg
1984-113B	15383	1984	ANIK D2	6.84 m	2.16 m	653 kg
1985-109B	16274	1985	MORELOS 2	6.62 m	2.16 m	646.5 kg
1990-034A	20570	1990	Palapa B2R	6.96 m	2.16 m	692 kg
1990-091B	20873	1990	Galaxy 6	6.6 m	2.2 m	709 kg
1994-043A	23185	1994	APSTAR 1	7.5 m	2.2 m	726 kg
2002-015B	27400	2002	ASTRA 3A	7.97 m	2.17 m	908 kg

- Objects chosen based on year of their launch and availability over Hawaii during campaign.
- Each object tracked for an entire night except for losses due to weather
- 5 second exposures with 5 second co add
- Cycled through ZYJHK filters with about 10 min per filter



Light Curves

